

Technology acceptance model: a literature review from 1986 to 2013

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Abstract With the ever-increasing development of technology and its integration into users' private and professional life, a decision regarding its acceptance or rejection still remains an open question. A respectable amount of work dealing with the technology acceptance model (TAM), from its first appearance more than a quarter of a century ago, clearly indicates a popularity of the model in the field of technology acceptance. Originated in the psychological theory of reasoned action and theory of planned behavior, TAM has evolved to become a key model in understanding predictors of human behavior toward potential acceptance or rejection of the technology. The main aim of the paper is to provide an up-to-date, well-researched resource of past and current references to TAM-related literature and to identify possible directions for future TAM research. The paper presents a comprehensive concept-centric literature review of the TAM, from 1986 onwards. According to a designed methodology, 85 scientific publications have been selected and classified according to their aim and content into three categories such as (i) TAM literature reviews, (ii) development and extension of TAM, and (iii) modification and application of TAM. Despite a continuous progress in revealing new factors with significant influence on TAM's core variables, there are still many unexplored areas of model potential application that could contribute to its predictive validity. Consequently, four possible future directions for TAM research based on the conducted literature review and analysis are identified and presented.

Keywords Technology acceptance model (TAM) · Literature review · Development and extension · Modification and application

1 Introduction

With the growing development of technology, particularly information and communication technologies (ICT), and its integration into users' private and professional life, a decision regarding its acceptance or rejection still remains an open question. In the last few decades, interest of the research community in addressing this question has resulted in the development of a number of theories and models of technology acceptance and its effective usage. The technology acceptance model (TAM), introduced by Fred Davis more than a quarter century ago, became a dominant model in investigating factors affecting users' acceptance of the technology. The TAM presumes a mediating role of two variables called *perceived ease of use* and *perceived usefulness* in a complex relationship between system characteristics (*external variables*) and potential system usage. Derived from the psychology-based theory of reasonable action (TRA) and theory of planned behavior (TPB), TAM has taken a leading role in explaining users' behavior toward technology. Without understanding the origins, development, and modifications along with the limitations of the model, there can be no comprehensive and methodical research in the field.

A thorough literature review was conducted aiming to offer a theoretical background of the field by analyzing ground theories and models that have influenced the development of TAM and furthermore addressing the majority of most important extensions, modifications, and

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applications of the model in the technology acceptance field.

The paper starts with a brief description of a methodology for the conducted concept-centric literature review and proceeds with an overview of the two psychology theories that represent a theoretical background for the emergence of TAM. Subsequent sections offer a reflection on TAM progress from 1986 onwards, presenting and organizing 85 selected scientific publications in three main categories such as: (1) literature reviews, (2) development and extension, and (3) modification and application of the TAM. This classification supports well the presentation of TAM research over the years. Some constraints of past and current work along with possible future research directions based on the literature review and analysis conducted are presented. The paper concludes by suggesting future directions and research possibilities, based on the recognition of the fact that there are still many unexplored areas of potential application of the model that could contribute to the validity of the TAM.

2 Methodology for the literature review

A review of prior relevant literature is an essential feature of any scientific study. The effective review creates a firm foundation for advancing knowledge; it facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed [17, 89]. To identify scientific publications that aim to investigate the TAM, a literature review that synthesizes published work was conducted. This concept-centric review made a broad search for the relevant publications on the topic rather than limiting the search to specific years or specific journals and/or conferences cf. [89]. Namely, such a limitation would have influenced the findings subjectively since firstly, research follows trends, and thus, specific research approaches might have been more common during certain periods of time and secondly, specific journals might encourage particular research approaches [38].

In order to identify relevant scientific publications addressing TAM, a structured approach following the suggestions of Webster and Watson [89] was adopted: (i) search on the particular keyword(s) in the leading journal databases; (ii) selection of publications with a matching criteria; (iii) quick scan of the identified publications by reading their titles, abstracts, and full text to select those relevant to TAM research; and (iv) detailed process of reading and analyzing a full text of the selected publication.

For the purposes of the review, the literature search was undertaken in a 3-month period during November and

December 2012 and January 2013. The following international online bibliographic databases were consulted:

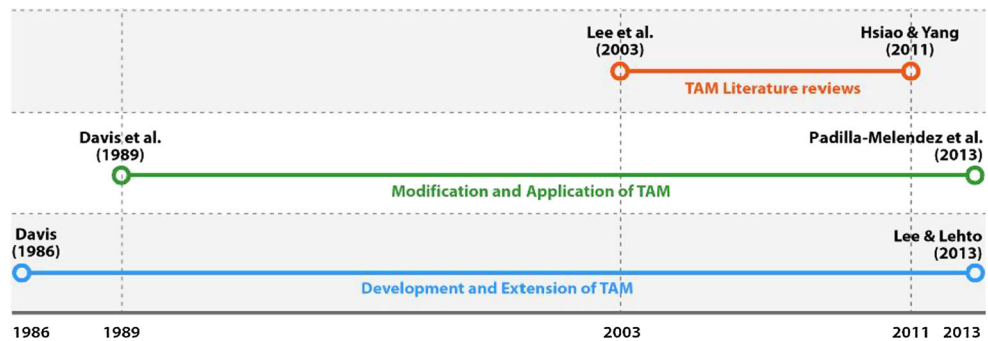
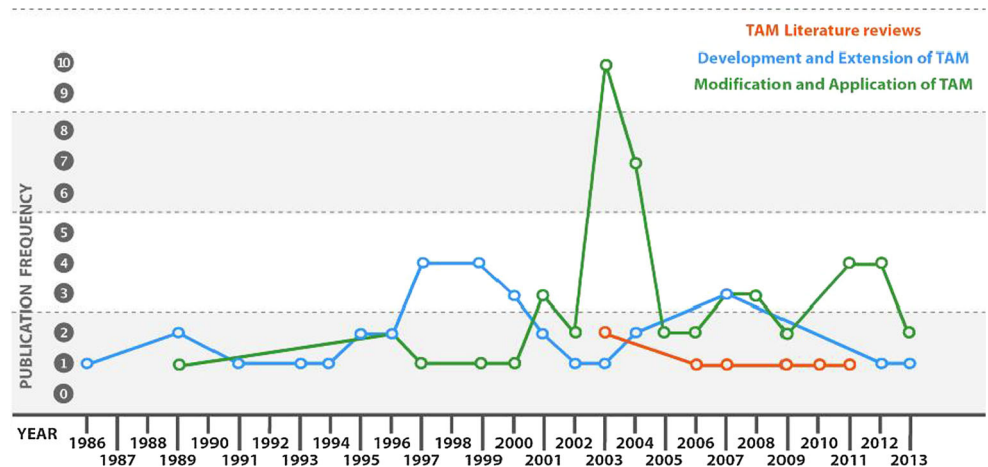
- ISI Web of Knowledge
- EBSCO Host (consisting of Academic Search Complete and PsycINFO)
- ACM
- ERIC
- ISI Web of Science
- ScienceDirect
- Google Scholar

The search string used was (“Technology Acceptance Model” OR “TAM” OR “Technology Acceptance”). Searches were limited to publications written in English and published in journals and conference proceedings, from 1986 onwards. The first constraint was posed due to the fact that this is the year when the TAM was proposed [20].

When the publication’s title or abstract seemed significant for the review, the full text was quickly scanned to ensure that the content was relevant to the model. The qualified publications were retained in the list and the irrelevant ones were eliminated, thus leaving for further analysis 170 publications dealing with TAM. A following step comprised a detailed process of reading and analyzing a full text of the selected publications bringing to a close a total of 85 presented in this review. Finally, those publications were categorized according to their aim and content into three categories: (1) TAM literature reviews, (2) development and extension along with (3) modification and application of TAM. Figure 1 offers an illustration of a time line in TAM research emphasizing some key years and published scientific literature.

The aim of this literature review is to offer a comprehensive summary of main research dealing with TAM, starting with its origins and concluding with directions for future work. As presented in the above figure, TAM progress in the past 27 years is organized and presented in the following three main categories:

- Literature reviews of TAM: publications addressing TAM literature reviews were a starting point to gain an overview of the technology acceptance field; authors of the selected publications provided various review methods of past work dealing with TAM providing insights and limitations;
- Development and extension of TAM: publications placed in this category share the same core elements of TAM, provide new insights related to TAM variables, and at the same time develop and/or extend it by creating new versions;
- Modification and application of TAM: work of authors interested in revealing new factors of TAM acquired

Fig. 1 Time line of TAM research**Fig. 2** Frequency of TAM publications

throughout the research and accordingly modifying the model are included in this category; most of, especially recent, the research deals with the application of different TAM modifications on specific systems in order to examine the models' predictive power on the one hand and to prove its applicability on the other.

Figure 2 brings the final selection of 85 publications placed in the aforementioned three categories; they are presented according to the frequency of their appearance. Authors' interest in the development and extension of TAM is reflected through more-or-less constant publication frequency throughout the inspected time period. Conversely, publications dealing with the modification and application of TAM had their peak in the year 2003. Incidentally, in that same year, the first TAM literature reviews were published. Most recently published scientific literature in all categories reveals current and still ongoing interest in understanding the acceptance of technology.

3 Literature reviews of TAM

Seven extensive TAM literature reviews emerged from the conducted review of the TAM research. The history of TAM and a prediction of its future trajectory are offered in

the work of Lee et al. [52]. They have analyzed and critically examined TAM and specified future directions. The research purpose of the study was to answer some crucial questions, such as progress and discoveries of TAM in the time period 1986–2003. Additionally, the future directions of TAM, emphasizing a need for incorporating more variables and exploring boundary conditions, were identified. In the same year, Legris et al. [53] have published an analysis of empirical research using TAM and showed that the results are not completely consistent and clear. They argued that significant factors are not included in the model; they have to be integrated into a broader one which would include variables related to both human and social change processes. King and He [48] conducted a statistical meta-analysis of TAM as applied in various fields. The results showed TAM to be a valid and robust model that has been widely used, thus implying its potentially wider applicability. Sharp [72] examined the development, extension, and application of TAM and identified three specific areas for future research: (1) mixed results of *perceived usefulness* and *perceived ease of use* as stronger determinant, (2) volitional versus mandatory use environments, and (3) role of attitude in user acceptance. On the other hand, Chuttur [19] indicated that although TAM is a highly cited model, there are mixed opinions regarding its

Table 1 Seven extensive TAM literature reviews

Author(s)	Review method	Main findings and conclusions
Lee et al. [52]	Analysis of TAM's history and prediction of its future trajectory	Progress and discoveries of TAM in time period 1986–2003; identification of future directions
Legris et al. [53]	Analysis of empirical research of TAM	Results not entirely consistent or clear; significant factors are not included in the model
King and He [48]	Statistical meta-analysis of TAM studies	Valid and robust model with potential of broader applicability
Sharp [72]	Examination of development, extension, and application of TAM	Identification of three specific areas for future research
Chuttur [19]	Analysis of theoretical assumptions and practical effectiveness of TAM	TAM lacks sufficient and rigorous research
Turner et al. [80]	Analysis of TAM in the context of technology usage prediction	TAM usage outside the context in which it has been validated requires thoughtful consideration
Hsiao and Yang [39]	Statistical analysis of TAM studies	Identification of three main trends in TAM application

theoretical assumptions and practical effectiveness. He concluded that the model lacks sufficient and rigorous research. Turner et al. [80] placed the research of TAM in a context of predicting technology usage and concluded that care should be taken using the model outside the context in which it has been validated. Hsiao and Yang [39] used a sequence of statistical analyses including factor analysis, multidimensional scaling, and cluster analysis, which helped them to identify three main trends in TAM application: (1) task-related systems, (2) e-commerce systems, and (3) hedonic systems.

The identified literature reviews of TAM mentioned above are presented in Table 1.

4 Origins of the technology acceptance model

For better understanding of the development and the emergence of TAM, a brief description of theories and models, which preceded and influenced its appearance, is required. At the very beginning of technology entering users' everyday life, there was a growing necessity for comprehending reasons why the technology is accepted or rejected. First, theories attempting to explain and predict those decisions were grounded in the field of psychology.

The theory of reasoned action (TRA), [4] along with the TPB, [2] represents the origins of TAM.

Ajzen and Fishbein [4] assumed that individuals are usually quite rational and make systematic use of available information. They developed a theory that could predict and understand behavior and attitudes. The TRA looks at the *behavioral intentions* rather than the *attitudes* as the main predictors of behaviors. In their theoretical model, Ajzen and Fishbein suggested that a person's actual behavior could be determined by considering her/his prior intention along with beliefs that the person would have for the given behavior [20]. According to their theory, a main predictor of the behavior is the *behavioral intention*, while the influence of the *attitude* on the behavior is mediated through the *intention*.

As the TRA began to take hold in social science, it became obvious that this theory was not adequate and had several limitations. One of the main limitations was with people who have a little or feel they have little power over their behaviors and attitudes. Ajzen [2] described the aspects of behavior and the attitudes as being on a continuum from one of little control to one with great control. To balance these observations, Ajzen added a third element to the original theory. This element is the concept of the *perceived behavioral control*. The addition of this element has resulted in a newer theory known as the TPB.

The TPB is an extension of the TRA. TPB was used to address the inadequacies that Ajzen and Fishbein had identified through their research using TRA, in particular the model's inability to deal with behaviors over which individuals have incomplete volitional control. At the heart of TPB is the individual's intention to perform a given behavior.

According to TPB, the individual's performance of the certain behavior is determined by her/his intent to perform that behavior. The intent is itself informed by *attitudes* toward the behavior, *subjective norms* about engaging in the behavior, and *perceptions* about whether the individual will be able to successfully engage in the target behavior or not. According to Azjen [2], an attitude toward behavior is a positive or negative evaluation of performing that behavior. The *attitudes* are informed by *beliefs*, the *norms* are informed by *normative beliefs* and *motivation* to comply, and the *perceived behavioral control* is informed by beliefs about the individual's possession of the opportunities and resources needed to engage in the behavior. TPB also includes a direct link between *perceived behavioral control* and *behavioral achievement*. Given two individuals with the same level of intention to engage in behavior, the one with more confidence in her/his abilities is more likely to succeed than the one who has doubts [3]. The purpose of the theory is to predict and understand motivational influences on the behavior that is not under the individual's

volitional control and to identify how and where to target strategies for changing the behavior.

A major limitation of TPB is that the theory only works when some aspect of the behavior is not under volitional control. The theory is based on the assumption that human beings are rational and make systematic decisions based on the available information; therefore, unconscious motives are not considered. Other problems include not taking into consideration factors such as *personality* and *demographic variables* as well as assumption that the *perceived behavioral control* predicts *actual behavioral control*, which may not always be the case [58].

Despite their limitations, both the TRA and the TPB provided useful models that could explain and predict the actual behavior of the individual. However, soon problems of adapting these models to the various contexts, like user acceptance of an information system, occurred. Most of the studies carried out failed to produce reliable measures that could explain system acceptance or rejection. In order to develop a reliable model that could predict actual use of any specific technology, Fred Davis adapted the theories of reasoned action and planned behavior and proposed the TAM. He considered that the actual use of a system is a behavior, and therefore, the TRA and the TPB would be suitable models for explanation and prediction of that behavior. However, Davis made two main changes to the TRA and the TPB models. Firstly, he did not take subjective norm into account in predicting an actual behavior and only considered the attitude of a person toward it. Secondly, he identified two distinct beliefs, perceived usefulness and perceived ease of use, that were sufficient enough to predict the attitude of a user toward the use of a system [20].

5 Development and extension of TAM

Almost three decades ago, a conceptual model [20] for technology acceptance emerged from the research and theories in the field of psychology. In the following years, we have witnessed the appearance of the original TAM model [20] as well as its simplified version called the parsimonious TAM [21]. The model kept on developing through the years of research and experienced various extensions, reaching the recent TAM 2 model [85]. Extensions implied that additional factors and variables suggested by authors were incorporated into the model in order to explain the predictors of TAM core elements.

5.1 Emergence and advancement of the technology acceptance model

In 1985, Fred Davis proposed the conceptual model for technology acceptance [20]. He suggested that the *actual*

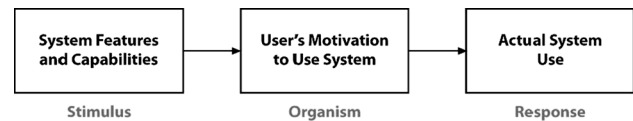


Fig. 3 Conceptual model for technology acceptance [19]

usage of the system is a response that can be explained or predicted by *user motivation*, which, in turn, is directly influenced by an *external stimulus* consisting of the actual system's features and capabilities, as shown in Fig. 3.

Davis [20] further refined his conceptual model to propose the TAM, which suggested that the user's motivation can be explained by three factors: *perceived ease of use*, *perceived usefulness*, and *attitude toward using* (as shown in Fig. 4).

Davis hypothesized that the *attitude* of a user toward the system was a major determinant of whether the user will actually use or reject the system. The *attitude* of the user, in turn, was considered to be influenced by two major beliefs, *perceived usefulness* and *perceived ease of use*, with the *perceived ease of use* having a direct influence on the *perceived usefulness*. Davis defined *perceived usefulness* as the degree to which the person believes that using the particular system would enhance her/his job performance, whereas the *perceived ease of use* was defined as the degree to which the person believes that using the particular system would be free of effort [72]. Finally, both beliefs were hypothesized to be directly influenced by the *system design characteristics* (represented by X_1 , X_2 , and X_3 in Fig. 4).

Davis and his associates additionally found that *attitude* did not fully mediate the *perceived usefulness* and the *perceived ease of use*. Based on these complementary findings, a parsimonious TAM was suggested, which removed the *attitude* construct from the model [21].

Subsequent TAM development has included *behavioral intention* as a new variable, which was directly influenced by the *perceived usefulness* of the system [23]. Davis and his colleagues suggested that there would be cases when, given the system which was perceived useful, an individual might form a strong behavioral intention to use the system without forming any attitude, thus giving rise to a modified version of TAM.

By eliminating the *attitude* construct and introducing the *behavioral intention* construct, the results obtained for the direct influence of *perceived usefulness* on the *actual system use* could be explained. At the same time, removing the *attitude* variable eliminated any unexplained direct influence observed from the *system characteristics* to the *attitude* variable. An additional change brought to the original TAM was a consideration of other factors, referred to as *external variables*, which might influence the beliefs of the

Fig. 4 Technology acceptance model [20]

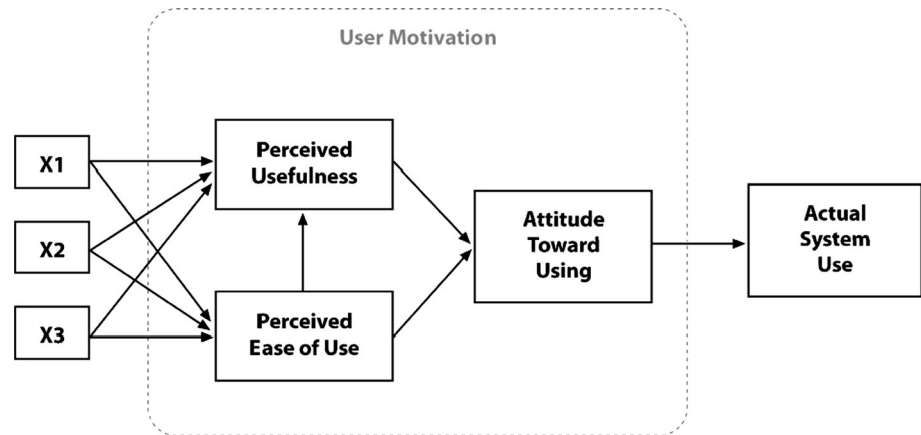
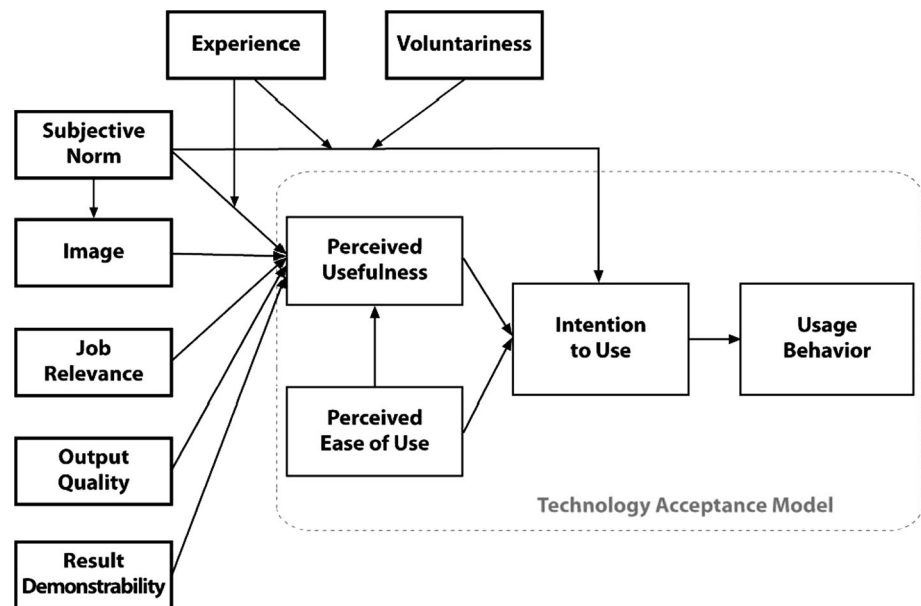


Fig. 5 TAM 2 [53]



person toward the system. The *external variables* typically included *system characteristics*, *user training*, *user participation design*, and the *nature of the implementation process* [84].

During later experimental stages, Davis has refined his model in order to include other variables and modify the relationships that were initially formulated. Similarly, other researchers have applied and proposed several additions to TAM. Doing so, over time, TAM evolved into a leading model in explaining and predicting system use. As a matter of fact, TAM has become so popular that it has been cited in most of the research that deals with user acceptance of technology [52]. However, some researchers, for example [19], claimed that TAM “may have attracted rather more easy and quick research, such that less attention has been given to the real problem of technology acceptance”.

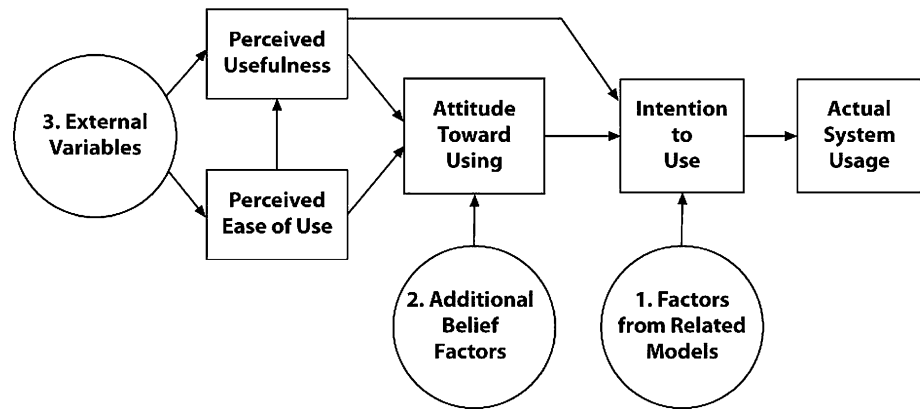
Due to the consistent findings that *perceived usefulness* was a major determinant of the *intention to use* [21, 23],

Venkatesh and Davis [85] proposed an extended model named TAM 2 (see Fig. 5). TAM 2 sought to identify the variables that influence the *perceived usefulness*. These variables included

- *subjective norm*: the influence of others on the user’s decision to use or not to use the technology;
- *image*: the desire of the user to maintain a favorable standing among others;
- *job relevance*: the degree to which the technology was applicable;
- *output quality*: the extent to which the technology adequately performed the required tasks; and
- *result demonstrability*: the production of tangible results.

Furthermore, *experience* and *voluntariness* were included as moderating factors of the *subjective norm*. Venkatesh and Davis conducted a longitudinal research

Fig. 6 Extensions of the technology acceptance model



including two voluntary environments and two involuntary environments. The pooled results across the studies and the time periods revealed that *subjective norm*, *image*, *job relevance*, and *result demonstrability* were significant determinants of the *perceived usefulness*. It was also shown that *subjective norm*, *perceived usefulness*, and *perceived ease of use* were direct determinants of the *intention to use* [85]. Such was the case in the original and the parsimonious TAM: *perceived ease of use* was a significant determinant of *perceived usefulness*. The only two-way relationship shown to be significant was between the *output quality* and the *job relevance*. The two-way relationships between the *subjective norm* and the *experience* along with *subjective norm* and *voluntariness* were not significant (*ibid*).

5.2 Key extensions of the technology acceptance model

After introducing various computer and information systems into organizations, user technology acceptance received fairly extensive attention. Researchers and practitioners devoted substantial research effort determining which factors affect user's beliefs and attitudes on the technology acceptance decision, and on the other hand which ones contribute to user's resistance. The TAM was widely used to study the adoption of various technologies, and TAM has arguably become the most influential theory. In order to address problems of understanding predictors of TAM variables, the model has been extended by incorporating new factors and variables with significant influence [90].

One of the most important extensions of TAM was proposed by Venkatesh [83], who was interested in identifying antecedents to the variable *perceived ease of use* of the model. Two main groups of antecedents for the *perceived ease of use* were identified: *anchors* and *adjustments*. The *anchors* were considered as general beliefs about computers and computer usage, whereas the *adjustments* were considered as beliefs that are shaped based on

direct experience with the target system. In both groups, Venkatesh proposed several determinants that were mostly derived from previous research related to the detection of the antecedents to the *perceived ease of use* [24].

As shown in Fig. 6, three major directions of TAM extension could be deduced from a vast number of studies, thus introducing new factors and variables to the TAM that could be grouped into

1. Factors from related models: a number of factors from related models have been brought in such as *subjective norm* [8], *perceived behavioral control* [59], and *self-efficacy* [79];
2. Additional belief factors: some factors from a diffusion of innovation literature additionally addressing belief construct have been introduced, such as *trialability* [1], *visibility* [47], *result demonstrability* [68], and *content richness* [49]; and
3. External variables: various external variables or moderating factors to the two major belief constructs (*perceived usefulness* and *perceived ease of use*) have been introduced as well, such as *personality traits* [32] and *demographic characteristics* [83, 86] or *computer self-efficacy* construct [18].

The core positions of the two belief constructs, *perceived usefulness* and *perceived ease of use*, can be clearly identified. Consequently, it could be claimed that a structure and main assumptions of these extended models remain the same as of the TAM.

The 32 publications related to the development and extension category listed in Table 2 present a history of TAM evolution.

6 Modification and application of TAM

After experiencing developments and extensions by introducing predictors for the basic TAM constructs, new TAM modifications emerged mostly as a result of “enhancement”

Table 2 Publications addressing the development and extension of TAM

Author(s)	Category	Main topic
Davis [20]	Development	Development of technology acceptance model (TAM)
Davis [21]	Development	Development of parsimonious TAM
Davis et al. [23]	Development	Introduction of <i>behavioral intention</i> as a new variable of the model
Mathieson [58]	Development	Comparison of TAM and TPB models
Davis [22]	Development	Realization of field study of TAM
Barki and Hartwick [8]	Extension	Introduction of the factor <i>subjective norm</i> to the model
Igbaria et al. [45]	Extension	Definition of two aspects of <i>motivation: extrinsic and intrinsic</i>
Taylor and Todd [79]	Extension	Introduction of the factor <i>self-efficacy</i> to the model
Chau [14]	Extension	Integration of TAM and personal computer utilization models
Venkatesh and Davis [84]	Development	Consideration of possible introduction of other factors referred to as <i>external variables</i>
Agarwal and Prasad [1]	Extension	Introduction of additional belief factor <i>trialability</i> to the model
Gefen and Straub [32]	Extension	Introduction of <i>personality traits</i> as external variables to the model
Jackson et al. [46]	Extension	Extension of the model to include <i>situational involvement, intrinsic involvement, and argument for change</i>
Straub et al. [75]	Development	Comparison of the TAM model across different cultures
Dishaw and Strong [27]	Extension	Integration of TAM and task-technology fit (TTF) models
Karahanna et al. [47]	Extension	Introduction of additional belief factor <i>visibility</i> to the model
Lucas and Spittler [57]	Extension	Extension of the model to include <i>social norms, user performance, and two control variables</i>
Venkatesh [82]	Extension	Consideration of role of <i>intrinsic motivation</i> as a lever to create favorable user perceptions
Venkatesh [83]	Extension	Identification of the <i>antecedents</i> to the <i>perceived ease of use</i> variable in the TAM model
Venkatesh and Davis [84]	Development	Development of TAM 2
Venkatesh and Morris [86]	Extension	Introduction of <i>demographic characteristics</i> as external variables to the model
Mathieson et al. [59]	Extension	Introduction of the factor <i>perceived behavioral control</i> to the model
Plouffe et al. [68]	Extension	Introduction of additional belief factor <i>result demonstrability</i> to the model
Brown et al. [9]	Development	Examination of TAM in a mandated use environment
Venkatesh et al. [87]	Development	Formulation and empirical validation of unified model, which integrates elements across eight models of technology acceptance
Lin and Wu [55]	Extension	Introduction of <i>intra- and extra-organizational</i> factors as causal factors of end user computing perception
Van der Heijden [81]	Development	Identification of differences in user acceptance models for productivity-oriented (or utilitarian) and pleasure-oriented (or hedonic) information systems
Arning and Ziefle [7]	Extension	Introduction of <i>subjective technical confidence</i> as moderating variable to the model
Gumusoy et al. [34]	Extension	Introduction of <i>subjective norms</i> and <i>educational level</i> factors to the model
Schepers and Wetzels [70]	Extension	Moderation of effects of one individual-related factor (<i>type of respondents</i>), one technology-related factor (<i>type of technology</i>), and one contingent factor (<i>culture</i>)
Chow et al. [18]	Extension	Introduction of <i>computer self-efficacy</i> construct as external variable to the model
Lee and Lehto [49]	Extension	Introduction of additional belief factor <i>content richness</i> to the model

and incorporation of supplementary factors resulting from the relevant research. Moreover, in order to test the model's applicability on the one hand and to enhance its predictive validity on the other, the applications of TAM on specific systems were identified as well.

Figure 7 illustrates TAM with four major categories of modifications [48]. The model incorporates

1. External predictors: external predictors for the prediction of the variables *perceived usefulness* and *perceived ease of use* such as *technology anxiety* [69], *prior usage* and *experience* [10, 63], *self-efficiency* [25], and *confidence in technology* [6];
2. Factors from other theories: factors from other theories of technology acceptance for increasing predictive validity of the TAM like *subjective norm* [35], *expectations* [87], *user participation* [5], *risk* [29, 67], and *trust* [30, 31, 92];
3. Contextual Factors: contextual factors which could have a moderating effect such as *gender* and *cultural diversity* [44, 64, 75] and *technology characteristics* [68]; and
4. Usage measures: usage measures for operationalization of actual system usage like *attitude toward technology* [23], *usage perception* [37, 61, 77], and *actual usage of technology* [26].

All aforementioned authors in their research have used the original or the extended versions of TAM. They have applied it on different systems by introducing new factors with an aim to increase its predictive validity as well as to better understand determinants of the technology acceptance. A great majority of studies have addressed the application of TAM on information and computer technology. Information systems have been studied by Hu et al. [41] who applied TAM to predict acceptance of information security technology. Furthermore, acceptance prediction of health care information systems [65] and clinical information systems [60] was addressed by applying extended TAM.

Close relation of the information and computer technology fields has been confirmed in several studies aiming to apply TAM on systems such as digital libraries [36], Internet-based information systems [93] as well as search engines for seeking information on the Web [54].

Internet technology is so far one of the most interesting areas of research due to its continuous growth reaching nearly exponential number of new users. In order to reveal factors influencing acceptance and usage of the Internet, Shih [73], Lee and Kim [50], and Lee et al. [51] have used the extended TAM. In addition, the need of studies which apply TAM on specific systems like electronic mail [71], Internet banking [12, 62], or Internet-supported medical

procedures [15] has risen as well. Castaneda et al. [11] have confirmed TAM adequacy in prediction of user intention to visit specific Web sites, while Huang [42] has used the same model while exploring Internet acceptance considering the gender of users. Wireless Internet technology, widely studied in the last decade, has produced several acceptance models based on TAM, including the model of wireless Internet acceptance [91, 94] and the model of mobile Internet acceptance [56, 74].

An area of great interest in incorporating new technologies, especially computer and Internet technology, is the field of learning and teaching. The educational system encompasses a wide range of potential users of technology that could help them in the process of knowledge transfer and acquisition. In that respect, the issue of technology acceptance or rejection could be crucial. Park et al. [66] and Farahat [28] have tested the application of the original TAM, while Gong et al. [33], Zhang et al. [95], and Cheung and Vogel [16] have used the extended TAM in the context of e-learning. The application of TAM for m-learning was in the focus of interest for Huang et al. [43].

A lot of recent research has been carried out in the applicability of TAM on a variety of technology where authors have tried to find and incorporate factors to enhance the predictive validity of the model. However, continuous development of new technologies as well as a growing number and diversity of users opens new directions of research that could raise understanding of the technology acceptance and contribute to potential TAM upgrade.

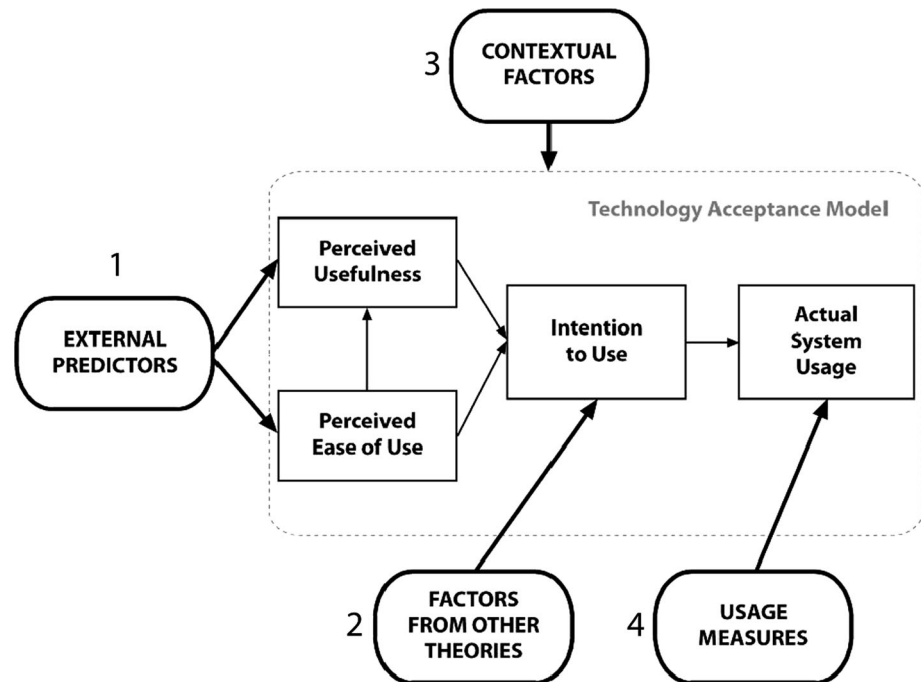
Table 3 shows 50 publications comprising research dealing with the modification and application category of TAM.

7 Possible future directions

A summary of the most influential studies of TAM was presented in the previous sections. The aim was to provide a comprehensive overview and deeper understanding of the technology acceptance field as well as to identify future directions and new research possibilities. This literature review revealed four most important courses for future TAM research:

1. The moderating role of individual variables: Even though a broad set of individual variables was included in the presented studies, there are some other user characteristics that could be considered as well as they might have a moderating effect on the relationship between TAM variables and technology acceptance [76]. Namely, research has already shown [7] that *cognitive abilities* are strong predictors of age-related

Fig. 7 Four major categories of TAM modification [48]



declines in *performance*, *perceived usefulness*, and *perceived ease of use*. Then again, the foremost cognitive abilities like *spatial and reasoning abilities*, *processing speed*, and *memory abilities* might also contribute to the explanation of technology acceptance and performance. Apart from cognitive resources, emotional factors such as computer anxiety or fear of failure and their interaction with gender or expertise should also be considered in the future research.

2. The incorporation of additional variables in the model: Even though TAM has already helped in explaining technology acceptance, a deeper understanding of factors contributing to TAM variables is required. An area of great potential is an examination of different information systems and environments. Some researchers, see, e.g., [82], suggested studies on multiuser systems and more complex technologies. Previous TAM studies investigated the effects of different environments and individual differences like *cultural differences* [14, 40, 75] and *gender* [32]. The results indicate that TAM may not predict technology use across all cultures and that women and men differ in their perceptions, though not in technology usage. These findings suggest that researchers should include cultural differences as well as gender in models dealing with technology acceptance. Nevertheless, more efforts in order to examine broader environmental factors, including *emotion*, *habit*, *personality difference*, and *technology change*, are necessary.

3. The investigation of actual usage and the relationships between actual usage and objective outcome measures: Research addressing relationships between the actual usage and the objective outcome measures (e.g., *performance*) is another issue that has to be examined. TAM studies were performed under the general assumption that the relationship between usage and *satisfaction* or *performance* is positive (e.g., [14]). However, only a few studies attempted to verify those relationships [45, 57] stating that perceived enjoyment and usefulness fully mediate the relationship between perceived ease of use and technology usage. Therefore, new studies are required in order to determine whether such an assumption can be supported by the empirical testing.
4. The target group of older adults: Results of numerous studies have confirmed that age plays a major role in the interaction with technology, e.g., [13, 88]. However, in this context, a critical remark about research samples should be additionally considered. Examined samples of older adults were not representative of a population for the older age group. Namely, the older participants involved were often comparably young and had a quite high educational level [7]. For that reason, future studies should examine more representative samples of older people. This is of special interest as older adults might particularly benefit from the utilization of new technologies (e.g., mobile devices serving as a memory aid).

Table 3 Publications addressing the modification and application of TAM

Author(s)	Category	Main topic
Davis et al. [23]	Modification	Incorporation of usage measure <i>attitude toward technology</i>
Davis and Venkatesh [25]	Modification	Incorporation of external predictor <i>self-efficacy</i>
Szajna [77]	Modification	Incorporation of usage measure <i>usage perception</i>
Straub et al. [75]	Modification	Incorporation of contextual factor <i>cultural diversity</i>
Hu et al. [40]	Application	Applicability of TAM in explaining physicians' decisions to accept telemedicine technology in the health care context
Venkatesh and Morris [86]	Application	Applicability of TAM in the context of individual adoption and sustained usage of technology in the workplace
Horton et al. [37]	Modification	Incorporation of usage measure <i>usage perception</i>
Moon and Kim [61]	Modification	Incorporation of usage measure <i>usage perception</i>
Plouffe et al. [68]	Modification	Incorporation of contextual factor <i>technology characteristics</i>
Chau and Hu [15]	Application	Applicability of TAM on Internet-supported medical procedures
Hong et al. [36]	Application	Applicability of TAM on digital library system
Featherman and Pavlou [29]	Modification	Incorporation of factor <i>risk</i> for increasing predictive validity of TAM
Gefen et al. [31]	Modification	Incorporation of factor <i>trust</i> for increasing predictive validity of TAM
Hardgrave et al. [35]	Modification	Incorporation of factor <i>subjective norm</i> for increasing predictive validity of TAM
Huang et al. [44]	Modification	Incorporation of contextual factor <i>gender</i>
Liaw and Huang [54]	Application	Applicability of TAM on search engine systems for seeking information on Web
Lu et al. [56]	Application	Applicability of TAM on mobile Internet
Oh et al. [63]	Modification	Incorporation of external predictor <i>prior usage</i>
Pavlou [67]	Modification	Incorporation of factor <i>risk</i> for increasing predictive validity of TAM
Venkatesh et al. [87]	Modification	Incorporation of factor <i>expectations</i> for increasing predictive validity of TAM
Yu et al. [94]	Application	Applicability of TAM on wireless Internet
Amoako-Gyampah and Salam [6]	Modification	Incorporation of external predictor <i>confidence in technology</i>
Chan and Lu [12]	Application	Applicability of TAM on Internet banking system
Davis and Venkatesh [26]	Modification	Incorporation of measure <i>actual usage</i> of technology
Gefen [30]	Modification	Incorporation of factor <i>trust</i> for increasing predictive validity of TAM
Gong et al. [33]	Application	Applicability of extended TAM in the context of e-learning
Shih [73]	Application	Applicability of extended TAM to reveal factors influencing acceptance and usage of Internet
Yi and Hwang [93]	Application	Applicability of TAM on Internet-based information systems
Hu et al. [41]	Application	Applicability of TAM on information systems
Huang [42]	Application	Applicability of TAM in exploring Internet acceptance considering the gender of users
Burton-Jones and Hubona [10]	Modification	Incorporation of external predictor <i>experience</i>
Saadé and Kira [69]	Modification	Incorporation of external predictor <i>technology anxiety</i>
Amoako-Gyampah [5]	Modification	Incorporation of factor <i>user participation</i> for increasing predictive validity of TAM
Castaneda et al. [11]	Application	Applicability of TAM on specific Web sites
Huang et al. [43]	Application	Applicability of TAM for m-learning
Park et al. [66]	Application	Applicability of original TAM in the context of e-learning

Table 3 continued

Author(s)	Category	Main topic
Serenko [71]	Application	Applicability of TAM on electronic mail system
Zhang et al. [95]	Application	Applicability of extended TAM in the context of e-learning
Lee and Kim [50]	Application	Applicability of extended TAM to reveal factors influencing acceptance and usage of Internet
Tao et al. [78]	Application	Applicability of TAM on business simulation games
Melas et al. [60]	Application	Applicability of extended TAM to predict acceptance of clinical information systems
Pai and Huang [65]	Application	Applicability of TAM on health care information systems
Wu et al. [91]	Application	Applicability of TAM on wireless Internet
Wu et al. [92]	Modification	Incorporation of factor <i>trust</i> for increasing predictive validity of TAM
Farahat [28]	Application	Applicability of original TAM in the context of e-learning
Lee et al. [51]	Application	Applicability of extended TAM to reveal factors influencing acceptance and usage of Internet
Nasri and Charfeddine [62]	Application	Applicability of TAM on Internet banking system
Son et al. [74]	Application	Applicability of TAM on mobile Internet
Cheung and Vogel [16]	Application	Applicability of extended TAM in the context of e-learning
Padilla-Meléndez et al. [64]	Modification	Incorporation of contextual factor <i>gender</i>

8 Conclusion

A respectable amount of work dealing with the TAM, from its first appearance more than a quarter century ago until the present when this review was written, clearly indicates a popularity of the model in the research field of technology acceptance. Originated in the psychological TRA and TPB, TAM has evolved to become the key model in understanding the predictors of human behavior toward potential acceptance or rejection of the technology. The strength of the model is confirmed by numerous studies emphasizing its broad applicability to various technologies.

In this comprehensive concept-centric literature review from 1986 onwards, 85 scientific publications have been selected according to the designed methodology. Selected publications have been classified according to their aim and content into three categories, which clearly embrace those addressing TAM literature reviews, development and extension of TAM as well as modification and application of the model. The classification and presentation of TAM-related works and publications in those three broad categories support well the presentation of TAM research over the years.

The conducted literature review has indicated continuous progress in revealing new factors with significant influence on the core variables of the model. Nevertheless, there are still various unexplored areas of potential application of the model that could contribute to the predictive validity of TAM. Consequently, four possible directions for future research are identified: the moderating role of individual variables, the incorporation of additional variables to the model, the investigation of actual usage and the relationships between actual usage and objective outcome measures, and the target group of older adults. A growing need for technology, especially ICT, in the professional and private life of users will certainly enhance the interest for the field of the technology acceptance for many years to come.

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